

Aortic valve damage caused by operative balloon dilatation of critical aortic valve stenosis

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SUMMARY Operative balloon dilatation of the aortic valve was performed in seven neonates with critical stenosis of the aortic valve. The procedure was followed by the development of severe aortic regurgitation in four patients. Necropsy was performed in three and revealed partial detachment of the right coronary cusp of the aortic valve. Damage to the valve leaflet caused by balloon dilatation was probably the result of using a balloon with a diameter that was too large in relation to the aortic valve ring diameter and of shearing forces created in the aortic wall by the contracting ventricle. The diameter of the inflated balloon should not be larger than the diameter of the aortic valve ring.

Percutaneous balloon dilatation of the pulmonary¹ or aortic valve^{2,3} has been used to relieve critical valvar stenosis in children and adults.⁴ Experimental and necropsy findings after this procedure have shown linear tears of the valve or transverse tears in the aortic wall.⁵ We report four cases of operative balloon dilatation of the aortic valve that damaged the valve leaflets.

Patients and methods

Seven infants underwent operative balloon dilatation of critical aortic stenosis presenting in the neonatal period.

CASE 1

A female baby presented in cardiac failure at the age of four days. Echocardiography and angiography revealed a ventricular septal defect, severe aortic stenosis, ductus arteriosus, and preductal coarctation. She underwent surgical repair of the coarctation with a Goretex gusset and ligation of the ductus arteriosus on the eighteenth day of life. Postoperatively episodes of acute left ventricular failure that were unresponsive to medical treatment developed and she required further mechanical ventilation. These episodes were caused by massive left to right shunting through the ventricular septal

defect, which was worsened by the critical obstruction of the left ventricular outflow tract. The echocardiographic estimate of the diameter of the valve ring was 6 mm. On the forty-seventh day the ventricular septal defect was closed surgically and at the same time balloon dilatation of the aortic valve was performed through an apical left ventricular stab incision with an 8 mm diameter balloon catheter. There was some improvement immediately after the operation but she died the next day.

CASE 2

A female baby presented with a systolic murmur and cardiac failure on the second day of life. Echocardiography revealed critical aortic stenosis with an estimated valve ring diameter of 5-6 mm. She developed clinical signs of necrotising enterocolitis on the second day, which responded to conservative treatment. She underwent operative balloon dilatation of the aortic valve on the sixteenth day with a 12 mm diameter balloon catheter but immediately bradycardia with low cardiac output developed, and she died in the operating theatre.

CASE 3

This 36 hour old male baby presented in cardiac failure. Echocardiography revealed critical aortic stenosis with a valve ring diameter of 6 mm. He was severely acidotic. He underwent operative balloon dilatation of the aortic valve with a 12 mm diameter balloon catheter on the second day of life. The procedure was followed by slow postoperative

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improvement but on the seventh postoperative day he collapsed because of septicaemia and died of a cerebral haemorrhage 24 hours later.

CASE 4

A female baby presented in cardiac failure 24 hours after birth. Echocardiography showed critical aortic stenosis with an 8 mm diameter valve ring. On the second day of life she underwent operative balloon dilatation of the aortic valve with an 8 mm diameter balloon catheter. Postoperative Doppler echocardiography showed satisfactory relief of the stenosis with a maximum gradient of 30 mm Hg but also showed the development of severe aortic regurgitation. She required further medical treatment and mechanical ventilation for left ventricular failure secondary to the aortic regurgitation, and aortic valve replacement was planned in view of her intractable cardiac failure. On the twenty-fourth day the aortic root was replaced by her own pulmonary valve; the coronary arteries were reimplanted with a homograft replacement to the right ventricular outflow tract. Immediately after this procedure bradycardia developed and she died in the operating theatre. Necropsy was not performed.

NECROPSY FINDINGS

In the first three cases postmortem examination of the heart showed dysplastic bicuspid aortic valves. In patient 1 the original orifice was narrowed to 2.5 mm in diameter, with a valve ring diameter of

4 mm. Further inspection of the valve disclosed a 3 mm tear that detached the base of the right side of the right coronary cusp from its attachment to the ring, producing aortic incompetence (fig (a)).

In patient 2 there was almost complete detachment (4 mm in length) of the right coronary cusp from its marginal attachment. There was also a linear longitudinal tear 5 mm long through the sub-valvar endocardium and the intima of the base of the aortic wall. This appeared to have been a consequence of the forcible detachment of the cusp (fig (b)).

In patient 3 the diameter of the aortic valve ring was 4 mm and the valve consisted of a thickened nodular dysplastic structure that had been split by a T shaped tear and partly detached from the margin over a 3 mm length on the posteromedial aspect (fig (c)).

The use of balloon dilatation in critical aortic stenosis was successful in three of our cases. Our four unsuccessful cases clearly represent the most severe end of the spectrum of critical aortic stenosis. Of the successful cases, patient A, a boy, had previously undergone open surgical aortic valvotomy for critical aortic stenosis (valve ring diameter of 3 mm) when he was 20 days old. Balloon dilatation of the aortic valve was performed for restenosis when he was eight months old. The echocardiographic estimate of the diameter of his aortic valve ring was 6–7 mm (gradient 80 mm Hg on Doppler echocardiography). A balloon catheter with an inflated

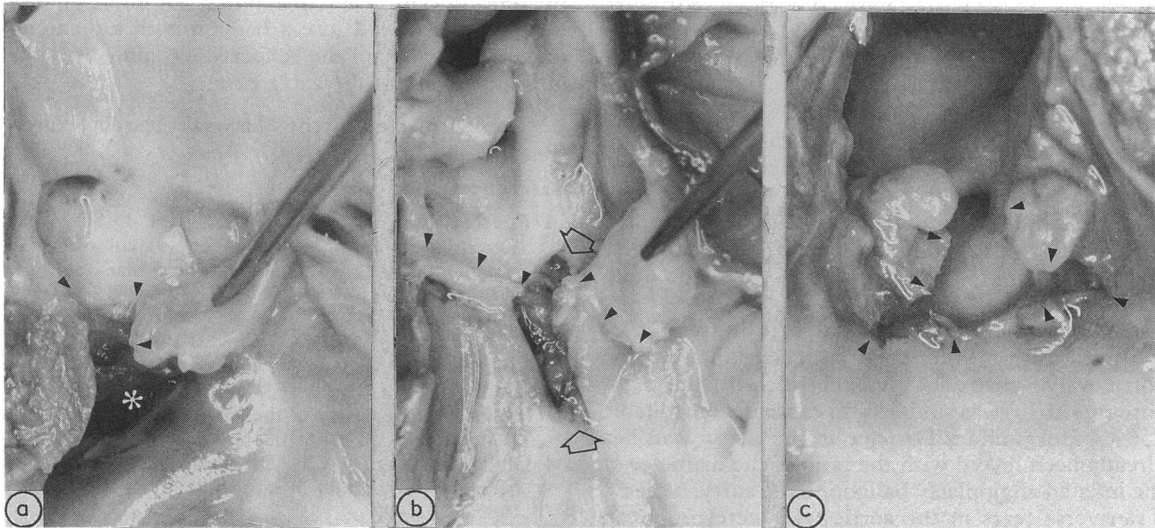


Figure The opened aortic valves and left ventricular outflow regions at necropsy in three patients. The small arrows indicate the extent of the cusp tears. (a) Female infant aged 47 days. Asterisk indicates ventricular septal defect. (b) Female infant aged 16 days. The open arrows indicate the additional longitudinal tear. (c) Male infant aged 9 days. The T shaped tear has divided the cusp and has also caused peripheral detachment.

diameter of 10 mm was used. Despite mild aortic regurgitation, he remains well clinically five months after the procedure.

Patient B, a boy, had repair of aortic coarctation at 23 days of age. Doppler echocardiography at the time revealed mild aortic stenosis (gradient 40 mm Hg with good left ventricular function). Cardiac failure due to severe aortic stenosis (gradient 90 mm Hg, valve ring diameter 10 mm) with a poorly contracting left ventricle developed when he was eight weeks old. Balloon dilatation of the aortic valve was performed with a 10 mm diameter balloon, and postoperatively Doppler echocardiography showed a maximum gradient of 30 mm Hg with mild regurgitation and improved left ventricular function. He remains well at six months of age.

Patient C presented in cardiac failure 14 days after birth. Doppler echocardiography showed critical aortic stenosis with a gradient of 60 mm Hg and a valve ring diameter of 8 mm. Operative balloon dilatation was performed on the fifteenth day with a 6 mm diameter balloon and her postoperative recovery was uncomplicated. Repeat echocardiography showed a Doppler gradient of 40 mm Hg with no aortic regurgitation and she remains well at four months.

Discussion

Nearly all infants with critical aortic stenosis die soon after birth. Palliative procedures, including open aortic valvotomy or percutaneous balloon dilatation, are associated with substantial morbidity and mortality. In our hospital we elected to use balloon dilatation rather than the conventional Hegar dilators because of the potential advantages of a narrower initial balloon diameter and a more controllable dilatation technique. In all cases the balloon was 3 cm long but because it became fusiform when inflated across the valve the usable length was only 2 cm. We did not find that the balloon protruded through the valve when we used a left ventricular stab incision but a shorter balloon would be more suitable and as effective.

Although there was an initial improvement after the procedure in our seven patients, injury to the aortic valve cusps in four (particularly the right coronary cusp) was sufficient to cause uncontrollable aortic regurgitation. Damage to the aortic wall has already been linked with the ratio of the diameter of the inflated angioplasty balloon to the aortic lumen.⁵ Transverse tears in the aortic wall were produced when a balloon with an inflated diameter similar to or larger than the diameter of the aorta was used. The aortic wall is elastic and is able to stand moderate stretching without damage, whereas the valve ring (in a dysplastic valve especially) is rigid and is more likely to tear at a degree of dilatation that does

not damage the aortic wall. This apparent tolerance of the arterial wall to stretching has been confirmed in animal experiments in which oversized balloons were inflated across the pulmonary valve⁶; major damage to the heart occurred in the outflow tract of the right ventricle. This study, however, was of normal pulmonary valves and thus the additional effect of the rigidity of a dysplastic valve could not be evaluated. Damage of the sort described above^{5,6} appeared to have occurred in our cases that came to necropsy, and in patient 2 the tear extended upwards into the aortic wall and downwards into the ventricle. The ventricular extension was very close to the bundle of His and damage to this structure may have been associated with the terminal bradycardia. The balloon size in these three cases was 8 mm, 12 mm, and 12 mm; in all three the diameter of the valve ring was 4 mm at necropsy. In patient 4 the balloon diameter was 8 mm and the valve ring diameter was 8 mm. The shearing effect of the inflated balloon in a contracting ventricle is a further probable cause of damage.

It seems that to avoid important damage both to the aortic wall and to the valve leaflets, while still producing effective dilatation of a critically stenosed aortic valve, a balloon with an inflated diameter of somewhat less than the diameter of the aortic valve ring should be used. Furthermore, the duration of balloon dilatation should be kept to a minimum to lessen the shearing force produced by the contracting ventricle.

We intend further evaluation of this technique for the relief of critical aortic stenosis, but in the light of our findings we will use a balloon with a diameter that is 70%–80% of the echocardiographic estimate of the diameter of the valve ring.

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